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Nile behaviour and Late Palaeolithic humans in Upper Egypt during the Late Pleistocene

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ABSTRACT

The reconstruction of the environment and the human population history of the Nile Valley during the Late Pleistocene have received a lot of attention in the literature thus far. There seems to be a consensus that during MIS2 extreme dry conditions prevailed over north-eastern Africa, which was apparently not occupied by humans. The Nile Valley seems to be an exception; numerous field data have been collected suggesting an important population density in Upper Egypt during MIS2. The occupation remains are often stratified in, or at least related to, aeolian and Nile deposits at some elevation above the present-day floodplain. They are rich in lithics and animal bones, mainly fish, illustrating the exploitation of the Nile Valley by the Late Palaeolithic inhabitants. The fluvial processes active during that period have traditionally been interpreted as a continuously rising highly braided river.

In this paper we summarize the evidence thus far available for the Late Pleistocene on the population densities in the Nile Valley, and on the models of Nilotic behaviour. In the discussion we include data on the environmental conditions in Eastern Africa, on the aeolian processes in the Western Desert of Egypt derived from satellite images, ^{14}C and OSL dates, in order to formulate a new model that explains the observed high remnants of aeolian and Nilotic deposits and the related Late Palaeolithic sites. This model hypothesizes that, during the Late Pleistocene, and especially the LGM, dunes from the Western Desert invaded the Nile Valley at several places in Upper Egypt. The much reduced activity of the White Nile and the Blue Nile was unable to evacuate incoming aeolian sand and, as a consequence, several dams were created in the Upper Egyptian Nile Valley. Behind such dams the created lakes offered ideal conditions for human subsistence. This model explains the occurrence of Late Palaeolithic hunter–fisher–gatherers in a very arid environment with very low Nile flows, even in late summer.

1. Introduction

In the scientific literature of the last decades, much attention was paid to movements of modern *Homo sapiens* from East Africa to the rest of the world (Carto et al., 2009; Stewart and Stringer, 2012). It is obvious that the Nile Valley and probably also Arabia (Petraglia and Rose, 2009; Armitage et al., 2011), thereby may have played a prominent role. The Nile Valley is indeed, within an often extremely dry North Africa, an oasis right through the Sahara (Wendorf et al., 1989; Phillips, 1994; Camps and Szmidt, 2009; Garcea, 2010, Drake et al., 2011). It should therefore come as no surprise that the population of the Nile Valley may have played a prominent role during the Late Pleistocene. DNA analyses have produced numerous conjectures how the Late Pleistocene population of the Nile Valley was subject to movements from north to south and vice versa (Manni et al., 2002; Lucotte and Mercier, 2003; Fadhlaoui-Zid et al., 2011). The understanding of the changing climate and its influence on the Nile regime and on human population densities, has made great progress. Field research in the Nile Valley has collected data that allow us to understand how the Nile Valley reacted to the changing climate and could create a favourable environment for Late Pleistocene humans.

In this paper, we will summarize the existing information on the Palaeolithic occupation of the Upper Egyptian Nile Valley, in order to describe the population densities through time, in particular of the Late Palaeolithic. Furthermore we examine the

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geomorphological situation of the Late Palaeolithic sites within the Nile Valley and reconsider the radiocarbon dates available in the literature to link these phenomena with climatic conditions. After describing the environmental reconstructions of the Nile Valley and the related models of Late Pleistocene Nilotic behaviour published by earlier authors, we finally propose a new model of Nilotic behaviour. This model is based on our own observations made during fieldwork since 1968, on interpretation of satellite images of the Western Desert of Egypt and the Nile Valley and on literature data about environmental conditions in Eastern Africa and the sedimentation rate from the Nile in the Mediterranean.

2. Setting

2.1. Late Pleistocene Nile Valley population

Research during the last decades regarding the Palaeolithic occupation of the Upper Egyptian Nile Valley (Vermeersch et al., 2000, 2006; Vermeersch, 2006, 2009, 2010; Schild and Wendorf, 2010; Van Peer et al., 2010) has made it clear that an expanded population was present during the Middle Stone Age (MSA, Middle Palaeolithic). Whereas very large chert extraction sites of the MSA have been recorded (Vermeersch, 2002), suggesting an important need for chert blanks, very few such sites of the Upper Palaeolithic have been found. The best explanation of this observation is that, during the Late MSA and the Upper Palaeolithic there was a low demand for raw materials because during MIS 4 and MIS 3 the population density in Upper Egypt declined sharply. Traces of humans dated later than 60,000 years ago became rare (Fig. 1). However, from about 24 ka calBP an important population increase is registered by the presence of numerous Late Palaeolithic sites. During the LGM there is indeed an abundant presence of humans along the Nile Valley in Upper Egypt. Numerous Late Palaeolithic sites are known (Vignard, 1923; Butzer, 1967; Smith, 1967, 1968; Wendorf, 1968; Wendorf and Schild, 1976; Kabacinski and Usai, 1999; Paulissen and Vermeersch, 2000) with Nilotic silts and clays deposited well above the present flood plain (See Supplementary Data 1). They are situated some metres above the present floodplain, most often where Nilotic clays meet local deposits (Fig. 2). Several human groups can be identified such as the Fakhurian, the Kubbaniyan, the Idfuan, the Sebekian, the Silsilian, the Afian and the Isnan, all of them characterised by fishing–hunting camps located in the present lower desert along the Upper Egyptian Nile (Smith, 1967; Wendorf et al., 1989; Vermeersch, 2010). Several sites have been excavated and, as the faunal remains are mainly of fish, attest the presence of intensive fishing activities. Mammalian fauna is very restricted and consists of aurochs (*Bos primigenius*), hartebeest (*Alcelaphus buselaphus*), dorcas gazelle (*Gazella dorcas*), hare (*Lepus capensis*) and hippopotamus (*Hippopotamus amphibius*).

Several clayey deposits with Late Palaeolithic sites date from around 14 ka calBP. Their origin was explained by high inundations of a “Wild Nile” (Paulissen and Vermeersch, 1987, 1989; Butzer, 1997). After 14 ka calBP there is an abrupt end of the human occupation presence. After that period indications of human presence in the Nile Valley are indeed very scanty and, with the exception of some rare Epipalaeolithic sites dating at about 9.0 ka calBP, the valley seems to remain empty until the end of the Saharan wet Holocene (Vermeersch, 1978).

In other parts of North Africa, the Upper Palaeolithic population seems to have been particularly low in number (Cremaschi and di Lernia, 1999; Barton et al., 2005; Linstädter et al., 2012; Douka et al., 2014). Upper and Late Palaeolithic people seem to be absent from the Saharan desert, or at least no sites attributed to such groups have been detected. Often the cause of the population decline has been interpreted as being the result of an increasingly drier climate. This situation contrasts heavily with that of the Upper Egyptian Nile Valley with its numerous sites.

2.2. Late Palaeolithic site chronology

From the calibrated conventional and AMS available ^{14}C dates (Fig. 3 and Supplementary Data 1), some of which are now rather old with a large standard error, and for some probably without an adapted fractionation, it can be observed that mainly two periods of occupation are present; a first from about 23 until 20 ka calBP and a

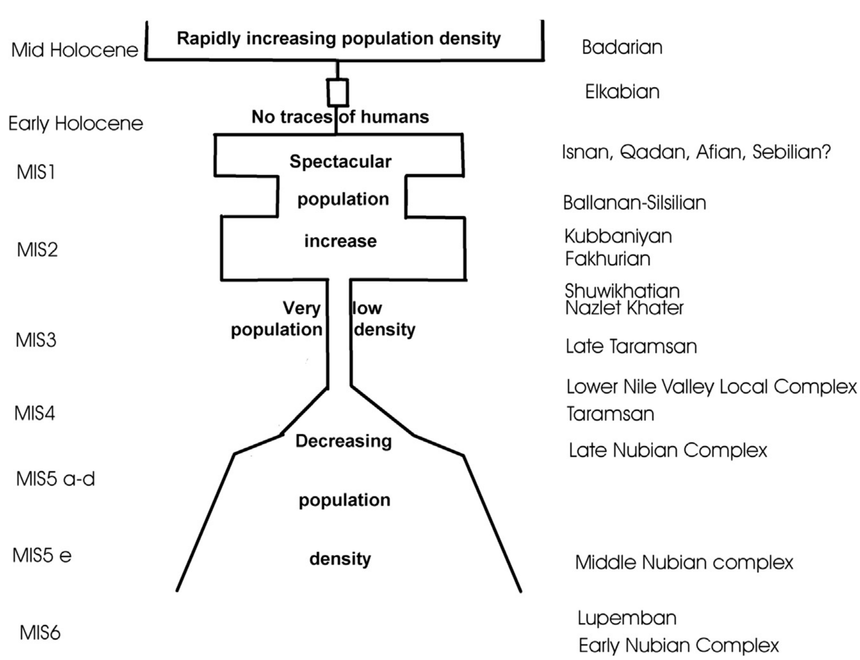

Fig. 1. A sketch of the evolution of population density in the Nile Valley in Upper Egypt (compiled from Wendorf et al., 1989; Vermeersch, 2009, 2010; Van Peer et al., 2010).

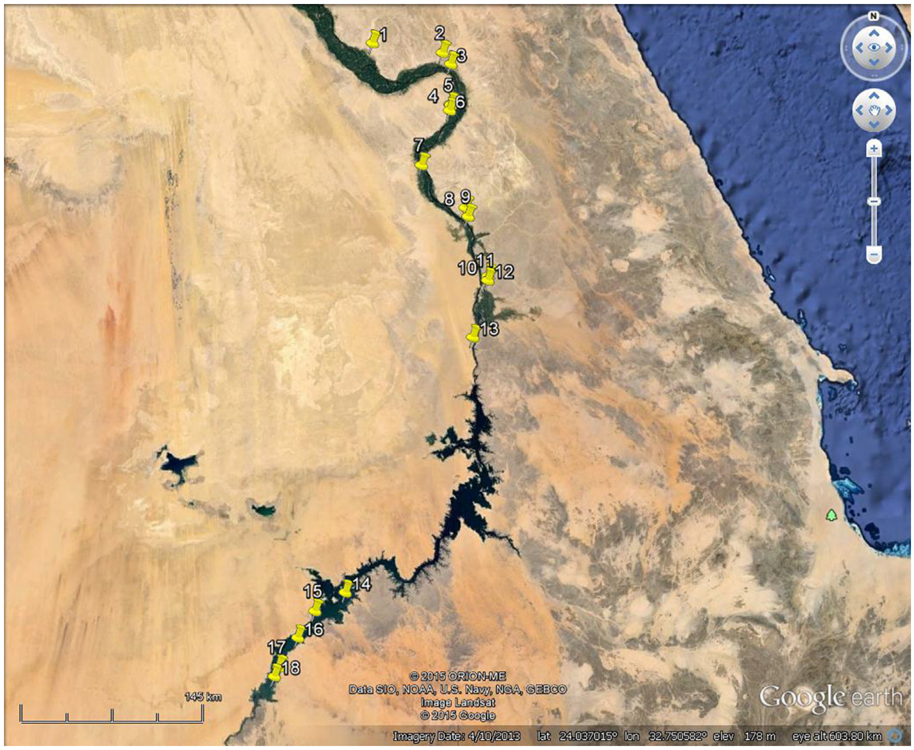

Fig. 2. Late Palaeolithic in the Upper Egyptian Nile Valley (Google earth). Sites mentioned in the text: 1: Nag el Elzba; 2:Makhadma; 3: Kumbelat “Nagaa Kom Bilal?”; 4: El Abadiya; 5: Deir el Abiad; 6: Nag el Zamami; 7: Isna; 8: Elkab; 9: El-Kilh; 10: Qurta; 11: Khor El-Sil; 12: Gebel Silsila (Kom Ombo); 13: Wadi Kubbaniya; 14: Tushka; 15: Ballana; 16: Faras; 17: Wadi Halfa; 18: Jebel Sahaba.

later one from about 16 until 14 ka calBP. In between the number of data is more restricted. During Heinrich Event 2 and the LGM an important cooling and dryness was observed (Krom et al., 2002), which coincides with the start of an important increase of human presence along the Nile in Upper Egypt.

There came an end to the visibility of human presence after 13 ka calBP and for a long period of several millennia no sites have been documented in Upper Egypt, except some rare Epipalaeolithic sites around 9.0 ka calBP (Vermeersch, 1978). Only with the end of the Holocene pluvial at about 5.5 ka calBP when Predynastic culture is developing, is a high number of sites observed in the area (Kuper and Kröpelin, 2006).

3. Natural environment according to earlier authors

Vignard (1923) discovered and published a sequence of new Palaeolithic industries described as Sebilian I, II, and III, from a series of platform-like ridges situated 3 km west of Kom Ombo. He interpreted these discoveries as occupation sites on the shores of a progressively shrinking lake, fed by local wadi systems, which had been dammed up behind Gebel Silsila for most of Palaeolithic times. According to Butzer (1967) there is no reason for assuming the existence of a large lake in the Nile Valley of southern Egypt. Butzer and Hansen (1968: 115) concluded that, at Kom Ombo, the Late Palaeolithic aggradation stage was the result of two or more major Nile channels, presumably braided. The main Fatira Channel near Kom Ombo was formed by peak discharges in the order of 10,300 m^3/s (the mean measured discharge at Aswan was 7500 m^3/s for 1912–73) (Butzer, 1997).

During the Late Pleistocene, the Mediterranean Sea was some 100 m lower. In response the Nile channel and distributaries were entrenched up to 30 m below the present surface of the delta. Just how far this incision was projected upvalley is uncertain (Butzer, 1997). However it seems acceptable that the entrenchment did not affect the Nile in Upper Egypt south of Nagaa Hammadi.

Williams and Adamson (1980) and Adamson et al. (1982) concluded from their work in the Nile headwaters that the river Nile during the end of the Last Glacial may have been so restricted that it did not flow during the dry season, and water may have been confined to pools in the deeper parts of the channels during much of the year.

Wendorf and Schild (1976), Schild (1987) and Schild and Wendorf (1989) proposed a model of the Late Pleistocene Nilotic behaviour where during alluviation the rainy season in the headwaters was shorter but still intense, and the total discharge was much less than today. With reduced stream competence and an increased sediment load, the Nile became a river flowing in numbers of braided channels across a floodplain, which rose continuously as more and more sediment was deposited. The Final Pleistocene Nile in Lower Nubia and Egypt could well have had an annual discharge only 10–20% of its modern volume. They agree that it is difficult to imagine this river: a comparatively small stream with a floodplain cut by several ephemeral braided channels, with little or no flowing water, but with each year a large flood after the seasonal rains at the headwaters. A series of exceptionally high floods, which may correlate with renewed flow from the White Nile, resulted in a final phase of silt accumulation on top of the sediments of a seepage lake at Wadi Kubbaniya, with a maximum elevation some 27 m above the modern flood plain. In reaction to the Schild–Wendorf model, Butzer (1997) replied that the Late Pleistocene record appears to be oversimplified, by implicitly referring apparent stages to an artificial model of aggrading or stable floodplains. The model of a highly braided river was nevertheless reaffirmed by Schild and Wendorf (2010).

According to Paulissen and Vermeersch (1987) the Nile Valley in Upper Egypt and Nubia was a suspended-load river and was

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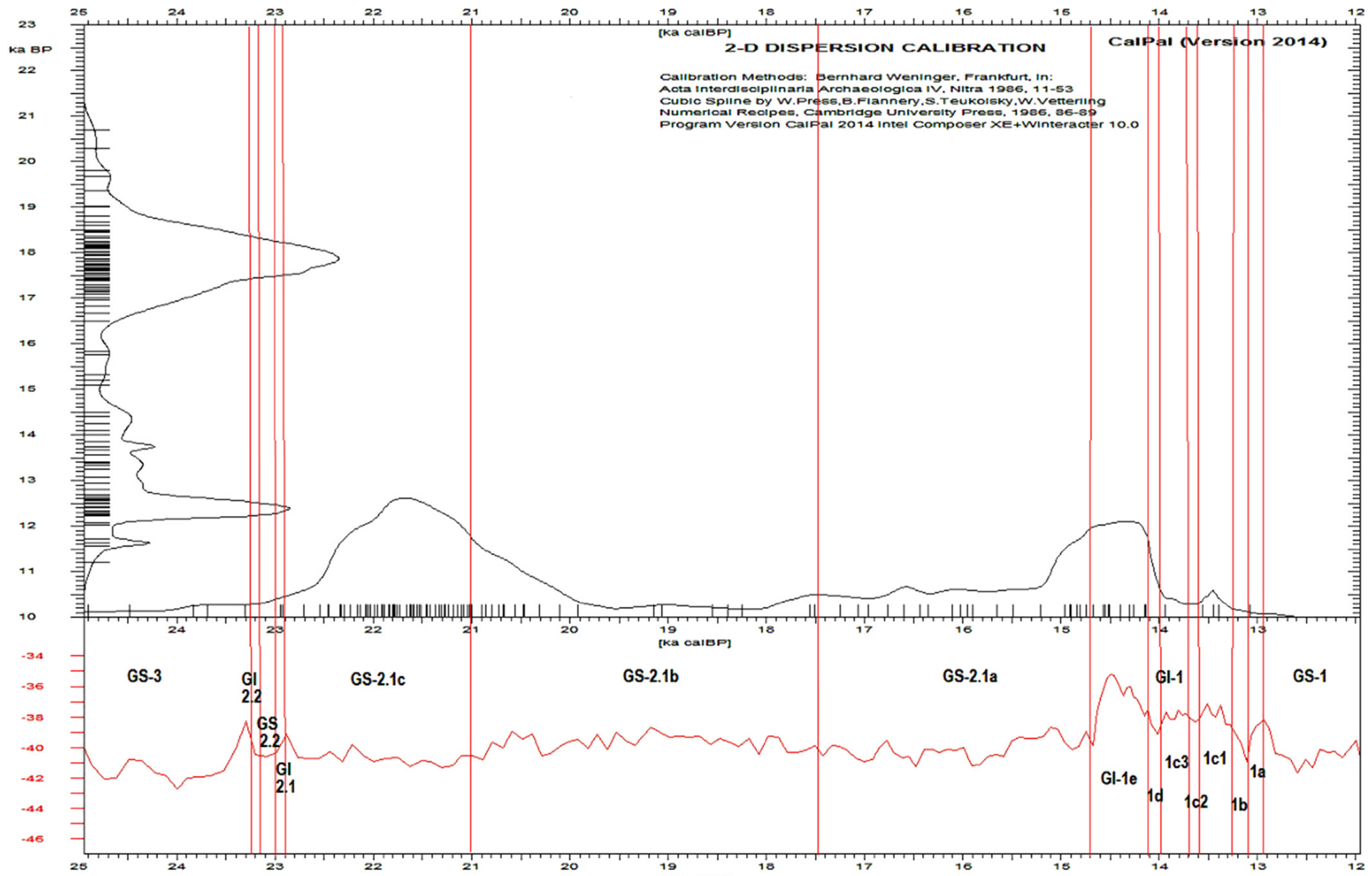

Fig. 3. CalPal of the available ^{14}C dates from Upper Egypt and Sudanese Lower Nubia (See Supplementary Data 1). Events dating (red vertical lines) according to Rasmussen et al. (2014) with GI (Greenland interstadial) and GS (Greenland stadial). The lower red line represents the GISP2 18O/16O curve. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

aggrading silts over a wide floodplain. The Shuwikhat silts, with their top dated to about 25 ka are the oldest dated Upper Palaeolithic silts. They are separated from the silts of the subsequent Sahaba-Darau or Kubbaniya aggradation by a period of Nile downcutting. The Wild Nile floods at 13–12 ka BP (15.5–14 ka calBP) were the most important catastrophic event in the Late Pleistocene history of the Nile.

In order to understand the geomorphology of the Nile Valley in Upper Egypt, one should not only take into account what happened in the headwaters of the river Nile but also what happened in the adjacent area, the Sahara, where aeolian activity was severe during the Last Glacial (Swezey, 2001). Swezey (2001) refers to some of the Wendorf–Schild sites (E9-12) as dated aeolian Quaternary localities, which he interprets in his Fig. 2 as being “times of eolian stabilization (by vegetation and/or pedogenic crusts) and burial by subaqueous deposits”. In that interpretation the LGM appears as a period of sediment stabilization without aeolian sediment mobilization. Such an interpretation is incorrect; the field data do not indicate the absence of aeolian activity. An alternation of aeolian and water sediments was clearly documented at the site of Wadi Kubbaniya, not registered in Swezey's contribution (Wendorf et al., 1989, cf. many profiles such as Fig. 3.35 and for more detail Fig. 28.5).

Wind directions reconstructed for Egypt's Western Desert from LANDSAT-MSS images indicate the dominance of N–S airflow from 30°N to 20°N, consistent with modern circulation (Fig. 2). A second direction of W–E appears over Western Egypt between 30°N and 26°N, and NW–SE between 26°N and 20°N (Brookes, 2003). During the LGM the longitudinal draa were modelled by strong trade winds (Bubenzer and Bolten, 2008). At the end of the Pleistocene, strong and dry westerlies pushed further to the south and deposited sand on the eastern slopes of the draa of Western Egypt. According to the OSL-dates (Table 1) obtained from such draa, their activity occurred mainly in the period between 24 and 11 ka BP.

In the Western Desert of Egypt, long sand streaks are revealed on satellite documents (Fig. 4). Barchan chains from the Faiyum depression appear to be shifting in a south-southeast direction. Some have reached the western borders of the Nile Valley (El-Baz and Wolfe, 1981).

Along the Middle Nile edge (Dayrout) a group of barchans and elongated sand dunes, the South Wadi El Rayan dune field (Fig. 4), show dramatic sand movement that is active even now (Embabi, 2004: 112; El Gammal and El Gammal, 2010; El Sayed and Alaa El Din, 2010). Important longitudinal dunes developed almost parallel to the Nile Valley. Said (1993: 143) has pointed out that in numerous texts from the Pharaonic period around 2200 BC there is mention of the frequency of sand storms and the accumulation of sand. This may be understood that, with the advent of aridity, dunes started to form along the western fringes of the river. In this stretch, aeolian sand and dune remains from the El-Khafoug formation inter-finger both the Prenile deposits of the Middle Pleistocene and the Neonile sediments of the Late Pleistocene (Said, 1981). Ordinarily these dunes, which formed during the winter storms, were flushed during the summer floods when these were high enough to wash the sand out. At times of low floods and extraordinary aridity, however, the dune and wind-driven sands

Table 1
OSL dates in ka from transverse and longitudinal draa in the Eastern Sahara (1–18) after Bubenzer et al. (2007) and from aeolian deposits covering rock art (20–22) after Huyge et al. (2011).

	Location	Lat. N	Lon. E	Mineral	Depth (m)	Luminescence technique	Luminescence age (ka)
1	Draa-East 6	27°19′	26°32′	K F	4.0	MAA IRSL	12.49 ± 3.01
2	Draa-Middle 2	25°24′	26°36′	Q	2.0	MAA GLSL	21.28 ± 3.00
3	Draa-Middle 3	27°12′	26°02′	Q	2.0	MAA GLSL	11.11 ± 1.76
4	Draa-Middle 4	27°12′	26°02′	Q	3.0	MAA GLSL	12.70 ± 1.81
5	Draa-Middle 5	27°12′	26°02′	Q	2.0	MAA GLSL	15.92 ± 2.05
6	Draa-West 1	25°07′	25°37′	Q	2.0	MAA GLSL	11.79 ± 2.97
7	Draa-West 2	25°07′	25°37′	Q	3.0	MAA GLSL	11.53 ± 2.09
8	Draa-West 3	26°12′	25°40′	Q	2.0	MAA GLSL	20.42 ± 3.82
9	Draa-West 4	26°12′	25°40′	Q	3.0	MAA GLSL	21.26 + 2–86
10	Draa-West 5	26°12′	25°40′	Q	4.0	MAA GLSL	21.90 ± 4.54
11	Draa-West 6	26°12′	25°40′	Q	5.0	MAA GLSL	22.84 ± 3.77
12	Draa-West 7	26°51′	25°36′	Q	2.0	MAA GLSL	17.09 ± 2.68
13	Draa-West 8	26°51′	25°36′	Q	3.0	MAA GLSL	18.05 ± 1.63
14	Draa-West 9	26°51′	25°36′	Q	4.0	MAA GLSL	20.35 ± 3.05
15	Draa	26°13′	28°31′	Q	3.0	SAR BLSL	13.20 ± 1.58
16	Draa	26°13′	28°31′	Q	4.0	SAR BLSL	13.48 ± 1.66
17	Draa	26°13′	28°32′	Q	2.2	SAR BLSL	29.66 ± 4.73
18	Draa	26°13′	28°32′	Q	3.2	SAR BLSL	36.37 ± 4.87
20	QII4.2.	24°39′	32°58′	Q	0.75	single-aliquot regenerative-dose (SAR)	13 ± 3.0
21	QII4.2.	24°39′	32°58′	Q	0.95	single-aliquot regenerative-dose (SAR)	17 ± 2.6
22	QII4.2.	24°39′	32°58′	Q	1.15	single-aliquot regenerative-dose (SAR)	16 ± 2.4

remained uncovered, slowly encroaching on the flood plain of the river and forming dune fields of great areal extent over the western bank (Said, 1993). At present, this dune field is mostly stabilized and is covered by a thin layer of Nile mud. However, even now some longitudinal dunes are invading the Nile Valley (Fig. 5).

4. Data for an alternative model

New research on the environmental conditions of the Upper Nile in Eastern Africa has produced important observations, which should be integrated in a model of Nile behaviour for Upper Egypt (Woodward et al., 2007). The lakes in headwaters of the White Nile (Williams, 2012) and the Blue Nile (Lamb et al., 2007) were drying out coeva1 with the weakening of the summer monsoon during the LGM. According to Revel et al. (2010) there was a very restricted sedimentation rate from the Nile in the Mediterranean. This was coeval (MIS 2) with a reduced water content of the East African lakes. Williams et al. (2010) have found that the Late Pleistocene White Nile in northern Sudan, south of Dongola, was still actively aggrading at 20.7 ± 0.2 ka calBP due to a phase of high flow in the main Nile.

It was observed that the relation of dune deposits to archaeology in both Sinai and the Negev, northeast of the Nile Valley, inferred a Last Glacial period of major aeolian sand sedimentation. OSL ages show that dunes in the Negev began to accumulate as early as ~23 ka in the south-west corner of the dune field. Following the LGM at ~21 ka, the dunes invaded the north-western part of the Negev (Goring-Morris and Goldberg 1990). The main dune-encroachment period occurred between 18 and 11.5 ka (Roskin et al., 2011), and thick aeolian sand deposits accumulated in the western Negev dune field. Stratigraphic studies show that during the Last Glacial period, when dune incursions in the Sinai–Negev erg began, what is now the Nile Delta area was characterized by a broad, sandy, minimally vegetated plain. Such conditions were ideal for providing a ready source of sand for aeolian transport under what were probably much stronger glacial-age winds (Roskin et al., 2011).

In the hyperarid conditions of the LGM and a natural non-irrigated Nile Valley, aeolian sand, introduced along the western fringes of the Nile Valley, was funnelled by the wide incised valley from Dayrout to the south-east (Vermeersch et al., 2006). The funnelling wind deflated the Nile sediments and, in addition to the sand introduced from the desert, found coarser sands in all the wadi cones. Huge amounts of sediment must have been brushed up the valley. It seems evident that the Nile bend at Nagaa Hammadi with east-west cliffs (Fig. 4) was a suitable place for abandonment of the traction load and the building up of a dune field. The sand accumulation in the valley during the LGM would have reached the southern and northern valley cliffs, damming the entire Nile Valley by dunes east of Nagaa Hammadi. At Nagaa Hammadi the material continued its south-eastern direction and even invaded the limestone plateau at Gebel el Gir (Figs. 4 and 10). Individual streaks can be followed over 50 km, even now crossing the plateau and accumulating in the Nile Valley near Armant, upstream of Luxor (Vermeersch et al., 2006).

The topographical situation upstream from Nagaa Hammadi shows that a dune field of 15 m high is sufficient to develop an endorheic basin and eventually a lake, reaching upstream even far beyond Qena (Fig. 8). Such a dam must be understood as large dune fields. Through seepage was minimalised as the suspension laden Nile waters clogged the pores. Eventually overflow channels in the dune field were easily repaired. Evidence for such a lake was found at Makhadma (Vermeersch et al., 2006). Vegetation along the lake shore captured the silty clay of the lake waters, creating clay rich shores, observed at nearly all Late Palaeolithic sites (Fig. 9). The "Sheikh Houssein Clays" near Makhadma (Qena) is such a typical suspension deposit, characterised by silty clay in which the sand fraction is lower than 5% (Paulissen and Vermeersch, 2000). Lowering through evaporation loss will lead to shrinkage cracks, often observed in the field.

Late Palaeolithic sites are often situated on dune sand near to silty sand deposits, the latter being interpreted as the result of a mixing of water laid silty clay deposits of a lake with dune sand of an invading dune body (Supplementary Data 2). During some periods the dunes became stabilised, as was attested at Wadi Kubbaniya (Wendorf et al., 1989).

On satellite images (Figs. 2, 4 and 10; Supplementary Data 3) it appears that the process of aeolian sand import into the Nile Valley could have happened at several places in Upper Egypt, especially between Luxor and Aswan. Indeed, at several places in Upper Egypt other traces of huge sand accumulations and an eventual damming of the Nile Valley can be presumed. One of them is still clearly

Fig. 4. Nile Valley in Middle Egypt (Satellite and aerial imagery provided courtesy GlobeXplorer.com and Partners, All rights reserved) with many sand streaks entering in and parallel to the Nile Valley. The red rectangle corresponds with the area of Fig. 8. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

visible NW of Armant, where dune sand crossing the crest of Gebel El Gir (Fig. 7) near Qena clearly is still building up barchans in the wadi. In its prolongation an aeolian accumulation provided a huge sand body near Armant, transverse to the Nile Valley (Fig. 10). The elongated sand accumulation (±2600 m × 600 m) transverse to the river at Armant, now built over by the village of Nagaa El Ghird, was already considered as dunes by the cartographers of Napoleon in the *Description d'Egypte*.[1] Its maximum elevation is still up to 6 m above the surrounding flood plain. It suggests that the Nile Valley could also be dammed at this spot. Some smaller streaks are still visible in the present valley (Fig. 10). The Nile Valley at Gebel Silsila and at Aswan are places also suitable for dam creation, eventually resulting in lake formation. The presence of an aeolian dam in Wadi Kubbaniya (Schild and Wendorf, 1989) suggests the possibility for incoming sand to dam the Nile Valley at this locality as well.

South of Aswan the remnants of Nile deposits are sometimes rather high above the flood plain (de Heinzelin 1968), which is probably not only the result of higher water stages, as suggested, but could also, at least partially, be the result of a Nubian uplift. Indeed, according to Thurmond et al. (2004) the Nubian Swell is an important tectonic feature of North Africa, with episodic but continuing uplift.

5. Discussion of a new model

5.1. Lakes in the Nile Valley as ideal site locations for surviving the harsh climate

The Schild–Wendorf model, a continuously rising highly braided river, is apparently not a model that fits with the

[1] Egypt Upper Nile, 1818 from the "David Rumsey Map Collection" for the Google Earth Browser (added as an overlay). Link to share: http://www.davidrumsey.com/view/google-earth-browser#egypt-up.

Fig. 5. Invading longitudinal dune (1985) in the lower desert south of Dayrout (Balansurah).

Fig. 6. Fresh traces of an intense abrasion by aeolian sand on limestone on top of the north flank of Gebel el Gir (Fig. 4).

environmental conditions of the LGM in the Nile Valley in Upper Egypt. There are indeed no indications that the whole Nile Valley over its entire width has ever been filled with deposits of a braided river. This would have been an extremely huge amount of deposits. If the Nile Valley deposits were indeed built up by a continuous higher braided river, the older sites should be situated at lower levels than the later sites, which is clearly not the case (Supplementary Data 2). Moreover, no channels of a braided river have been found. From a hydrodynamic point of view it must be stressed that high inundations necessitate extreme discharges, tens

Fig. 7. On the north flank of Gebel el Gir, a dune is progressing over the cliff face, forming a sand streak on top of the plateau. It will continue until it descends into the Nile Valley at Armant.

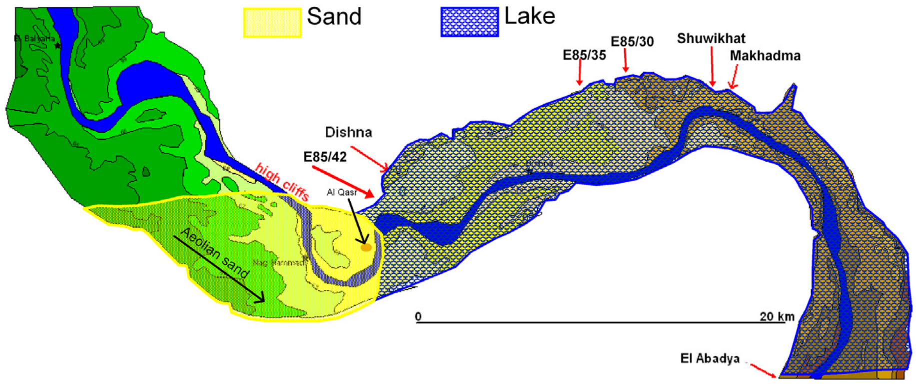

Fig. 8. Topographic map with suggestion of the extent of the aeolian sand accumulation and a lake, Makhadma Lake, behind a dune field at Nagaa Hammadi (for position see Fig. 4). Late Palaeolithic sites probably positioned along the shore of the lake are indicated (Hassan, 1974; Vermeersch, 2000; Vermeersch et al., 2006).

of times stronger than the pre-dam floods, which would change the valley in a channel, precluding all sedimentation of suspension charge and resulting in strong erosion both vertically and laterally.

When looking for another model that could apply to the LGM Nile Valley, some models developed in other areas can help us to understand what happened in the Nile Valley. Loope et al. (1995) came to the conclusion that during prolonged arid intervals in latest Pleistocene and middle Holocene times, aeolian dune sand blocked two large valley systems in western Nebraska. These blockages raised the water table of the High Plains aquifer as much as 25 m over an area of 7000 km^2 and created over one thousand lakes.

Even during the Last Interglacial period an extensive lake probably filled the White Nile Valley, extending into the arid zone of Sudan (Barrows et al., 2014). It was presumed that three important morphological features contributed to the damming: a major linear dune field from the west, a narrowing White Nile Valley and a damming of the White Nile by the Blue Nile.

All this leads us to suggest another geomorphological model of the LGM Nile Valley environments (Vermeersch, 2010) that takes into account the impact of the intense aeolian activity in the Sahara (Supplementary Data 3) and in the Nile Valley itself. A damming of the Nile at Nagaa Hammadi, at Armant and also at other places in Upper Egypt during the LGM is indeed of great probability. The presence of lakes in the Nile Valley during the LGM could offer humans excellent possibilities of food exploitation in otherwise very harsh climatic and environmental conditions. It can moreover be expected that several lakes at several places in the Upper Egyptian Nile Valley could have existed simultaneously during the LGM because damming is not related to Nile discharge alone but presumably even more to the intensity of aeolian activity. It is not expected that all dammed lakes would have had the same elevation above the present flood plain. It is therefore understandable that there is no correlation between cultural identity and accepted time period of the sites and their elevation above the present flood plain. There are indeed no indications that human sites, later in time, have

Fig. 9. Site Abadiya 3 (Vermeersch et al., 2006), where the flat transgressive lake deposits (grey clayey area central right) with faunal remains (inset) are thinning out against older deposits. Humans settled at the edge of the lake.

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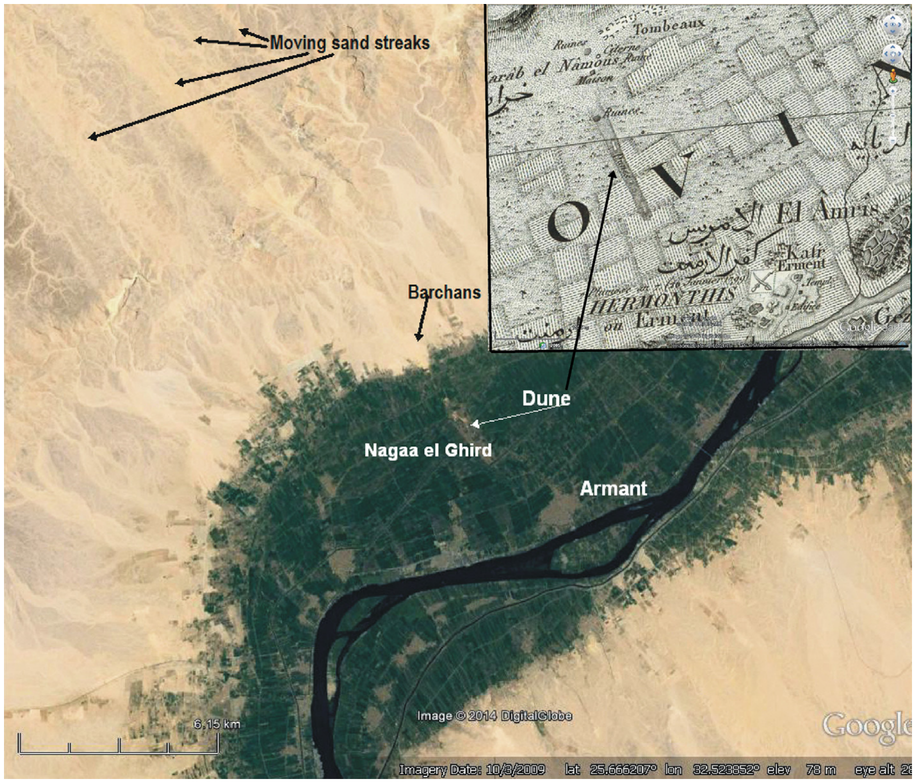

Fig. 10. Moving sand streaks on the plateau between Nagaa Hammadi and Armant and the dune at Armant, transversal to the Nile Valley, together with the inset of the map of the *Description d'Egypte* (Google Earth).

a higher elevation above the present flood plain than earlier ones. Consequently, the Late Palaeolithic sites associated with a lake level cannot be related in age to the elevation above the present floodplain, as would have been the case when the Nile Valley was, according to the Schild–Wendorf model, filling up by a continuously rising braided river. The "idealized reconstruction of evolution of the landscape at Isna" (Wendorf and Schild, 1976, Fig. 49) is even better understandable when the high Nile levels, which would have had a high erosion potentiality, are indeed Nile lake levels. The sediments in the interdunal ponds are mainly clayey (Supplementary Data 2). Moreover, deposits related to the occupations are either dune sand or silty clay and never coarser deposits, as is the case with a braided river system. In Upper Egypt, deposits which can be related to a lake sedimentation process are never very thick because they have been preserved only on the edges of the Late Pleistocene palaeolakes.

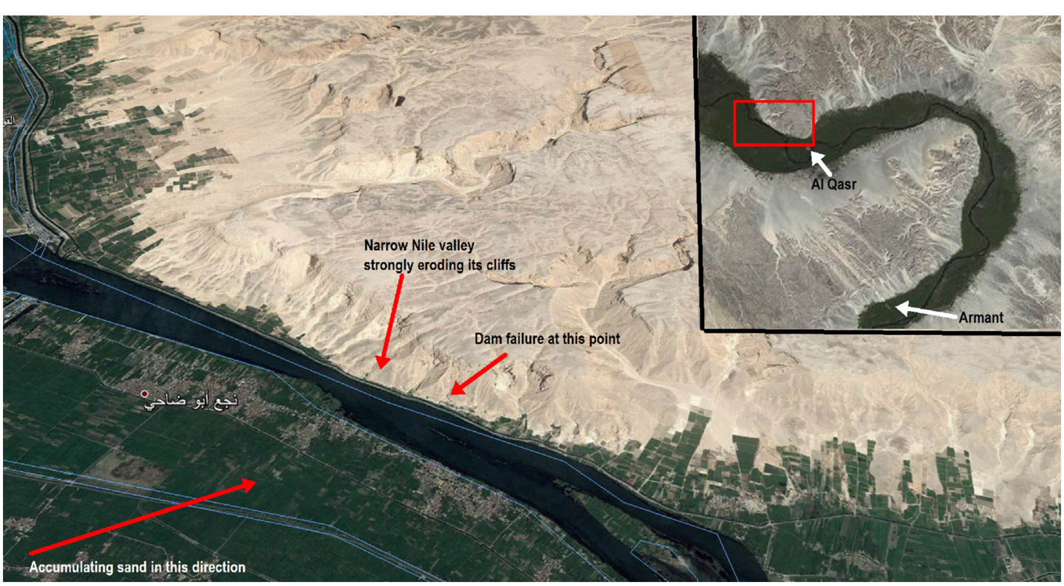

Fig. 11. Possible position of the failure of the dune dam, upholding the Makhadma Lake (Google Earth).

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When the East African lakes did not overflow, resulting in reduced discharge, the dunes in the Upper Egyptian Nile Valley were able to maintain or restore the dams, creating a favourable environment for hunter–fisher–gatherers. Such a situation seems to be the result of a long period of dune accumulation resulting in occasionally high dune complexes in the valley at the end of the LGM. It can be accepted that some lakes have existed for a long time (centuries, decades?). However, it seems unlikely that lakes, created as a result of the damming of the Nile, were always of long duration. At the occasion of a slightly larger water supply during the late summer, smaller dams could eventually be breached. Lake levels were not constant but of course influenced by percolation, evaporation or restricted flood water during the late summer season.

There is no need to presume that all dammed lakes in the Nile Valley were almost permanent during the whole LGM. Even when such information is not yet available, one can presume that sometimes a late summer discharge was exceptionally high; partially or even fully destroying a dam or several dams. Such events can be responsible for the very restricted Nilotic accumulation in the Mediterranean Sea (Revel et al., 2010). However, the aeolian accumulation was able to regain its position and create a new dune at the same place, or at another position, starting a new lake.

The rarity of sites attributed to the period after 20 ka calBP suggests that the Nile Valley became less attractive for fishermen (Fig. 3). Indeed, the near absence of ^{14}C dates for that period during the Greenland Stadial 2.1b (Fig. 3) can be understood as the result of a phase of higher flow in the main Nile observed near Dongola with a date of 20.7 ka calBP (17,540 ± 120 OZ1988) on shell (?) (Williams et al., 2010). As a whole, the ^{14}C date sequence of the Nilotic sediments and the correlated sites corresponds quite well with the succession of Greenland interstadials and stadials (Rasmussen et al., 2014). However, it is clear that stadial GS-2.1b is behaving in the Nile regime as wetter than GS-2.1a and GS-2.1c (Fig. 3).

The youngest sites are most often the highest above the floodplain, such as the Wadi Kubbaniya site E-81-5 attributed to the very Late Palaeolithic Isnan with a date 12,430 ± 100 BP (SMU-1032). Here a complex lacustrine sequence in the wadi was observed at an elevation of 23 m above the present floodplain (Schild and Wendorf, 1989), suggesting that, occasionally, the damming dunes in a wadi could be very high due to percolation of an even higher Nile (lake).

The longevity of some lakes can be deduced from the composition of the fish fauna (see Supplementary Data 2). Indeed, as argued below, at some places like Makhadma 4 (Van Neer et al., 2000), Kubbaniya E-81-3, E82-3 and E-81-4 (Gautier and Van Neer, 1989) the presence of mainly tilapia suggests that the waterbody was a lake environment rather than a river of which seasonal ponds were exploited. Late Palaeolithic fish faunas along the Egyptian and Nubian Nile are always characterised by a heavy preponderance of clariid catfish, usually of large individuals. This pattern has been explained as a result of fishing activities carried out on the floodplain at the beginning of the floods. Other floodplain dwelling taxa such as tilapia, and sometimes cyprinids, can occur, but their proportions are usually minimal (Gautier and Van Neer, 1989: 125 and 153; Van Neer, 2004: 256). The ichthyofauna of Makhadma 4, however, is composed of a very high proportion of tilapia (62% of the identified remains in the 4 + 2 mm sieved residues). High proportions of tilapia have also been reported from some sites at Wadi Kubbaniya. It is worth noting that both E-81-3 and E-81-4 are located around a shallow basin. Site E82-3 has a comparable fish spectrum but lies on the dunes farther inland Wadi Kubbaniya. Several studies monitoring the effects of artificial damming of African rivers have shown that profound changes occur in the species composition of the fish fauna and that these ichthyofaunas typically become dominated by tilapia (e.g., Petr, 1975). In Lake Nasser, the proportion of tilapia in the fish landings increased from 27% to 90% during the first 15 years that the lake was at working level (Agaypi, 1992) and still today these fish are the major species landed. It is clear that, in geological terms, damming of rivers such as the Nile has an almost immediate effect on the fish fauna. Descriptions of present day tilapia catches in function of fishing efforts in dam lakes show moreover that yields are low when the annual drawdown is too large or too fast (Bernacsek, 1984: 42). High proportions of tilapia at Makhadma are therefore more in agreement with long lasting lake environments than with a more irregular, unpredictable Nile regime that was previously invoked ('Wild Nile' floods), or with lakes that undergo a severe seasonal decrease in water level as a result of percolation. The existence of a lake environment is also supported by the incremental study on the tilapia otoliths from Makhadma 4 (Van Neer et al., 1993), showing a prolonged exploitation within the year. Also the length-frequency distributions of the tilapia (Van Neer et al., 2000: 277) point in the same direction: the expected bimodal distribution of the first two year classes is blurred due to an overlap between the cohorts. This overlap could be related to the extended period during which young fish were captured each season, but also to the length of the growth season that varied over successive years of fish exploitation as a result of variation in the lake levels. The presence of the bivalve species *Corbicula consobrina*, which is typical of sandy bottoms of large perennial waterbodies, is consistent with a permanent lake environment. The other mollusc species *Valvata nilotica*, *Bulinus truncatus*, *Gyraulus ehrenbergi* can be considered characteristic of stagnant, shallow waters, such as a vegetated lake side environment. Thick deposits of *C. consobrina* have been observed at Abadiya (Paulissen and Vermeersch, 2000).

Schild and Wendorf (2010) have objected to this new model arguing that no other lacustrine sediments such as calcareous marls and diatomites, characteristic for the lake dammed by the wadi dune at Wadi Kubbaniya, are present. One should however understand that the lakes in the Nile Valley were fed, even on an irregular basis, by Nile water, which is not favourable for such deposits.

Liu and Coulthard (2015) identified a total of 230 globally distributed study sites where, mainly in North Africa, but also in Namibia, Asia and Australia, river and dunes were observed to be interacting with each other. According to their "Classification of interaction types" the Nile Valley behaviour during most of the LGM should be considered as being of the "Fully aeolian dominant" type, and eventually during some periods as the "Alternating" type. Even if there was no significant relationship between interaction type and dune type, for the Nile Valley we should consider longitudinal dunes invading from the Eastern Desert as the main dune type involved.

5.2. Dam breaching

A series of about 30 radiocarbon dates from the Late Pleistocene deposits in Upper Egypt calibrates very clearly with the Bølling period, GI-1e (Fig. 3). Such an observation can be understood when we presume that at the end of the LGM (GS-2.1a), the damming dune fields were at their highest level. Several ^{14}C dates correspond to the dry cold period (GS-2.1a) preceding the warming up period of the Bølling (GI-1e). Dates continue to be present in the first part of the Bølling, but then came to an abrupt end. The warmer conditions of the Bølling coincide with higher discharge from both the Blue and the White Nile and led to the overflow of Lake Tana as well as Lake Victoria (Talbot et al., 2000; Williams et al., 2006; Marshall et al., 2011). The ^{14}C chronology of the youngest Late Palaeolithic sites (Supplementary Data 1) suggests that they coincide with the transition from the pleniglacial to the Bölling period, GI-1e (Fig. 3). This situation resulted in very high lake levels behind the Nagaa Hammadi dam and in the other lakes of Upper Egypt, until the discharge was able to breach all damming dunes. For the Makhadma Lake, we presume that the damming dunes were the weakest at the northern part of the Nagaa Hammadi bend farthest away from the incoming sand. The dam failure probably occurred at that point and resulted in the creation of the fresh erosional cliffs on the right bank, north of Nagaa Hammadi (Fig. 11). It seems possible that the higher ground (1.2 × 0.7 km in the valley), up to 8 m above the floodplain at Al Qasr (Figs. 8 and 11), could be a remnant of that earlier dune field. Moreover, west of Nag Hammadi, even now in the present day, the floodplain still remains somewhat drier, as can be read from satellite pictures.

After the final dam failures around 14.2 ka calBP, coeval with the period when the White and the Blue Nile restarted their influx of water into the Nile Valley, the recreation of an eroding meandering river brought an end to the important period of human occupation during the LGM; indeed, no sites are dated to the Younger Dryas. Once the damming dunes were breached and with higher discharges, the Nile deeply incised the lake deposits and was able to erode most of the damming dunes.

Dam breaching was apparently a catastrophic event for the humans in the valley. An incising valley reduced the fishing potential and created a very small floodplain, where humans and animals could not find enough food to sustain a large population. As a consequence humans may have become violent while competing for food. It is tempting to see the burial place at Jebel Sahaba in Nubia, attributed to the Qadan and dated at 15–14 ka calBP, as an indication of such a critical situation. Indeed, nearly half of the buried humans show traces of a violent death (Wendorf, 1968; Holl, 2013). According to Judd (2006), after a new study of the skeletal material, the idea that people lived in a stressful and violent society remains to be questioned. Albeit that there are few indications of bad health, there is no doubt about the violent death of many individuals. During the final Tardiglacial no traces of an Egyptian population are found in the Nile Valley. Even when new groups of humans are populating the deserts, very few traces of humans are found in the Nile Valley (Kuper and Kröpelin, 2006; Vermeersch, 2012).

In this new model the observations made by Butzer (1997) at Kom Ombo could be interpreted as the result of several dam breaches, which at some very specific moment could release a huge amount of water, creating a very short high peak discharge.

6. Conclusion

After a decrease in human occupation of the Upper Egyptian Nile Valley during the MIS 5 to MIS 3 period, an important population increase is registered by the presence of numerous Late Palaeolithic sites from about 24 ka calBP. During the whole LGM, Late Palaeolithic humans along the Nile Valley in Upper Egypt relied on hunting and, in particular, fishing for their subsistence. These activities took place in and along lakes that were formed when the Nile Valley was dammed by aeolian sand during the LGM. Aeolian sand was transported along the western Nile Valley cliffs until it was accumulated where the Nile changed its S–N course into an E–W direction, such as at Nagaa Hammadi. Here and at other places, eventually directly from the Western Desert, sand was invading and damming the Nile Valley. As Nile flow was quite reduced, the river was unable to erode all the incoming aeolian sand. The Nile water with its important clay content was stored in dammed lakes in the valley.

In this new model the observations made in Eastern Africa and Southern Sudan by Williams et al. (2010) can be integrated. Towards 27 ka calBP the lake levels in the White Nile headwaters were starting to fall and the Sudd swamps were shrinking, allowing the White Nile to carry substantial volumes of sand into its lower reaches. By 18 ka calBP the Uganda lakes were dry or very low, so that overflow into the White Nile had ceased. The Sudd swamps dried out. Dunes were active at least 50 km south of Khartoum along both banks of the lower White Nile, which was probably dry for most of the year. The Blue Nile was a highly seasonal river, as was the main Nile. Flow in the White Nile resumed with the abrupt return of the summer monsoon at 14.5–15 ka calBP, leading to overflow from the Ugandan lakes. The Sudd swamps became re-established and trapped all but the finest sediment. There seems to be an abrupt end of the Egyptian Late Palaeolithic occupation after 14.0 ka calBP, which we believe is related to the breaching of all aeolian dams in the Upper Egyptian valley.

New field work is needed to better implement this new model, mainly by the analysis of other Late Palaeolithic sites and the remains of the contemporaneous Nilotic deposits and aeolian sand bodies. It would be of great importance to check the age of such sand bodies in the Nile Valley by optical stimulated luminescence.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quascirev.2015.03.025.

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